NASA STTR 2005 Phase I Solicitation

T5 Johnson Space Center

To achieve the Agency's mandate of a robust space exploration program, the Johnson Space Center's roles and goals are focused on advancing the development of highly effective and innovative crew support and robotics/virtual digital human technologies. Extensive mission durations and harsh environments will dictate that future space explorers will need significantly improved hardware and systems to permit them to achieve these objectives. The Johnson Space Center, recognized as a Center of Excellence for human operations, seeks innovative solutions to these major challenges for human space explorers.

Subtopics

T5.01 Advanced Crew Support Technology

Lead Center: JSC

Advanced Crew Support Technologies will be essential to provide capabilities to enable humans to live and work safely, effectively, and efficiently in space during long-duration missions away from Earth as outlined by the Vision for Human Exploration of Space. Special emphasis is placed on development of technologies that will have a dramatic impact on reduction of mass, power, volume and crew time, and increased safety and reliability. Areas being solicited include Advanced Life Support and Extravehicular Activity including development of direct energy conversion, energy storage, and applications utilizing nanotechnologies relevant to these areas. Research and technology development with dual uses pertinent to Earth-based applications to improve environmental sustainability are of interest.

Life Support and Habitation (LSH)

Closed-loop life support systems were identified by the President's Commission on Implementation of United States Space Exploration Policy as an enabling technology critical to attainment of exploration objectives within reasonable schedules and affordable costs. Subsystems are needed to fully recycle air and water, recover resources from solid wastes, and produce food from plants. Requirements include: safe operability in micro-and partial-gravity, high reliability, minimal use of expendables, ease of maintenance, and low system volume, mass, and power. Specific areas of interest include:

- Waste Management: Technologies to safely and effectively manage dry and wet solid wastes expected on near-term missions (plastics, food scraps, clothing, paper, tape, hygiene materials, and/or feces) performing the following functions: compaction, stabilization, dewatering, storage, and control of odor release;

- Water Recovery: technologies in two specific areas are solicited: 1) low-temperature catalysts for destruction of organic carbon and nitrogen residuals in processed wastewater that operate at temperatures below 100º C; 2) technologies for recovery of water from brines generated from primary and secondary water processors including distillation and reverse osmosis systems that do not require use of consumable media;

- Filtration of Air and Water: techniques and technologies for separation and removal of particulates from water and gas streams, including air, potable water, and wastewater, that are regenerable, do not require consumable materials, have low pressure drop, and are suitable for use in micro- and hypo-gravity including consideration for collection and disposal of the solid phase;

- Food Provisioning and Galley: proposals are being sought in two areas: 1) Development of a non-metallic, high barrier packaging material with less mass and volume and/or is biodegradable, recyclable, or reusable, to minimize a potentially significant trash management problem. All packaging materials must have adequate oxygen and water barrier properties to maintain the food's 3- to 5-year shelf life. 2) Development of efficient and reliable food preparation or food processing equipment that can be used in hypogravity and reduced atmospheric pressure;

- Habitation Systems: Clothing Management Systems for reuse of clothing during long duration spaceflight, including clothes washing and drying technologies and which consider new advances in fabrics and materials;

- Crop Systems: new or more efficient technologies for lighting systems for crop growth, for use for fresh vegetable production within spacecraft or crop production systems on planetary surfaces. Lighting technologies must provide high irradiance and meet the spectral requirements for crops. These may include development of highly efficient electric light sources, highly efficient systems for collection, distribution, and re-emission of solar radiation or selectively transparent materials for direct solar lighting;

- Nanomaterials Applications: proposals are also solicited for development of advanced life support technologies that utilize unique properties of nanomaterials that are not possible with conventional materials, with emphasis on applications using single wall carbon nanotubes; and

- Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety and maintainability commensurate with in-cabin applications in crewed vehicles.

Advanced Extravehicular Activity (AEVA)

Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, operating lifetime, and increased human comfort. Specific areas of interest are as follows:

- Lightweight Structural and Protective Materials: proposals are sought for development of lightweight structural and protective materials for use in space suits to provide integral shell structure strength, impact, and puncture protection from shape edges, micrometeoroids and orbital debris, radiation protection, and prevention of abrasion, adhesion, and mitigation from Lunar and Martian dust;

- Protective Suits for Hazardous Environments: proposals are sought for development of a protective suit based on EVA technologies and concepts for Homeland Security and hazmat applications including hazardous materials handling and minimizing exposures to chemical and biological agents;

- Airlocks with minimum gas loss and volume: proposals are sought for development of both in-space and surface vehicle airlocks that minimize gas loss during depressurization and repressurization operations and also require minimum volume for airlock hatch and EVA crewmembers.

- Nanomaterials Applications: proposals are also solicited for development of technologies for Advanced Extravehicular Activity that utilize unique properties of nanomaterials that are not possible with conventional materials with special emphasis on applications using single wall carbon nanotubes; and

- Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in operating temperature range, in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety commensurate with in-cabin and exterior applications in crewed vehicles.

T5.02 Robotics and Virtual Digital Human Technologies

Lead Center: JSC

An Integrated Approach with Digital Virtual Humans(DVH) and Robotic Simulations

NASA is targeting a new level in space exploration operations. Critical advancements in crew and ground support technologies will be needed as NASA develops new operational capabilities to support multiple-manned, robotic, and long-duration/distance missions. Two potential areas for research are the ever-evolving Robotics and 3D DVH training procedures and simulation technologies providing operational robustness and intelligence. Furthermore, advanced capabilities for information integration and real-time interaction provide foundation for more simulation interaction between the two technologies. More advanced inter-system support capabilities (performance, maintenance, etc.) coordinated with a reliable knowledge base will be needed.

Proposals that improve operator efficiency via advanced displays, controls, and telepresence interfaces and improve the ability of humans and computers to seamlessly control robotic systems are sought. Specific technology requirements include the following hardware:

- Thermal feedback device for protecting the Robotic End-Of-Effector from grasping a hot/cold object that will damage its hand;

- Tactile feedback interface for collision awareness between workspace and avatar objects and robotic structure;

- Force feedback device for operator awareness of manipulator and payload inertia, gripping/slipping force, and forces and moments due to contact with external objects;

- Stereographic/autostereoscopic display systems for high-fidelity depth perception, field of view, and high resolution; and

- Spatial tracking for user appendages (i.e., head, arms, legs, fingers, and eyes) and avatar/robotic motion.

Based on the new Mission Control Center System (MCCS) Architecture framework, integrated support for Digital

Virtual Human (DVH) in the loop and teleoperational interfaces are also the focus of this solicitation. Proposals offering innovation in the form of 3D visualization and simulation capabilities of robotic systems (direct manipulation, telerobotics, telepresence, etc.) with relation to the 3D DVH in the loop concept are being sought. The application targets would be flight and ground operations development, analyses, planning, training, and support. The main result desired is an interactive system that enhances operator and IVA/EVA procedure tasks efficiency via the teleoperational technologies and distributed collaborative virtual environments. The introduction of the DVH in a Virtual Reality (VR) robotic scenario is necessary for task and robotic device design, development, testing, planning, training, and operations functioning as integrated systems.

The core element of this project is the implementation of the Digital Virtual Human (DVH). This innovative human modeling technology comprises a combination of anatomical, biomechanical, and anthropometric functionality to fully simulate the somatic components and systems of the human body. Based on the tenets of the Visible Human Project, this DVH technology provides the opportunity to simulate real-world problems on the DVH in a simulated, virtual environment (VE) interfacing with virtual objects. The main objective is to apply a high-fidelity DVH in a scenario that "re-creates" a real world. Scenes involving the DVH imply rich, complex problems to solve, visualize, and predict outcomes. The DVHs will have a key role in Shared VEs and truly interactive scenarios based on real-time data/information. More complex DVH embodiment increases natural interaction within the environment. The users' more natural perception of each other (and of autonomous actors/avatars) increases their sense of being together and thus the overall sense of shared presence in the environment.

Immersive technologies such as Virtual Reality (VR), Digital Virtual Human (DVH), and 3D DVH training procedure and simulation modeling have become a significant vehicle for NASA's effort to generate and communicate knowledge/understanding to K-12 levels through university/academic institutions to continuing education modalities. The ability to share aerospace-related operation simulations such as International Space Station and Space Shuttle/Space Transport System (STS) operations, robotics, intravehicular/extravehicular activities, Mission Control Center Systems (MCCS) conduct, interplanetary space flight, and microgravity simulation provides opportunity for educational and commercial growth for NASA and its research and development partners.

Human/Robotic Operations in Space

- Small, low power machine advanced vision systems for tracking a moving, articulated object;
- Machine vision techniques including the construction of image mosaics, for detection of unspecified changes in objects being inspected under diverse or changing lighting and viewing conditions;
- Small, lower power, range/range-rate sensors;
- Control interfaces that allow for seamless human/robot operations;
- 3D path planning systems and intelligent trajectory assessment feedback during teleoperations;
- Miniaturized motor control and drive electronics;
- Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque; and
- Reduced-part-count miniaturized propulsion hardware (e.g., compressed gas storage with output pressure regulation via valve control only).